The Standard Model

Part of the University of London post-graduate lectures in high-energy physics

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Detailed syllabus

1 Introduction and Overview (7 hours)

- The fundamental forces and particles
- Renormalisation and the Higgs
- Key measurements at colliders and elsewhere
- Key concepts: cross section, luminosity, Natural units

TOTAL: 8.5 hours

2 Special relativity (2 hours)

- Quick introduction: four-vectors, Lorentz transformation, light cone
- Relativistic kinematics, centre-of-mass energy, Mandelstam variables, rapidity

TOTAL: 10.5 hours

3 Relativistic spin-0 particles (1 hour)

- The Klein-Gordon equation
- Perceived problem in the Klein-Gordon equation
- Feynman-Stückelberg interpretation of negative energy solutions

TOTAL: 11.5 hours

4 Relativistic spin-1/2 particles (4.5 hours)

- Non-relativistic description. Pauli matrices, commutation relations, rotations in 3D, SU(2)
- The Dirac equation, α and β matrices and γ matrices
- The adjoint Dirac equation and the conserved probability current
- Solutions of the Dirac equation
- Orthogonality and normalisation
- Spin, γ^5 and helicity
- Completeness relation
- Possible forms of interaction in the Dirac theory

TOTAL: 16 hours

5 Calculating amplitudes (1 hour)

- Possible approaches
- Propagator approach

TOTAL: 17 hours

6 Spinless $e^-\mu^-$ scattering (3 hours)

- Concepts of local gauge invariance, gauge interactions and symmetry breaking
- Electrodynamics of spinless particles
- Definition of the cross section
- Number of final states
- Flux factor
- Cross section evaluation

TOTAL: 20 hours

7 $e^-\mu^-$ scattering (3 hours)

- Electron in an EM field
- Trace theorems
- $d\sigma/d\Omega$ for the process

TOTAL: 23 hours

8 e^+e^- annihilation to $\mu^+\mu^-$ (2 hours)

- Obtain from above scattering result
- R at e^+e^- colliders
- Helicity conservation at high energies

TOTAL: 25 hours (and handover)

9 Particles as quantum fields (4 hours)

- Content of the Standard Model
- Scalar fields
- Fermionic fields
- Gauge theories and vector fields.

TOTAL: 27 hours

10 Massive gauge theories and spontaneous symmetry breaking (6 hours)

- Short range interactions - massive gauge bosons
- Spontaneous symmetry breaking - Goldstone's Theorem
- Higgs mechanism - abelian and non-abelian

TOTAL: 33 hours

11 Electro-weak sector of the Standard Model (6 hours)

- Gauge bosons and spontaneous symmetry breaking
- Lepton sector
- Quark sector

TOTAL: 39 hours

12 Parity, charge conjugation, CP violation (3 hours)

- Parity, charge conjugation and time reversal symmetries.
- CP violation
- Neutrino masses

TOTAL: 42 hours

13 Weak interactions (4 hours)

- Leptonic processes
- Hadronic processes
- CP violation

TOTAL: 46 hours

14 QCD (7 hours)

- Symmetries and interactions
- Renormalization and running coupling
- $e^+e^- \to$ hadrons
- Deep inelastic scattering - partons, factorization

TOTAL: 53 hours

15 Collider Phenomenology

- Monte Carlo Event Generators
- Jets and jet substructure
- Electroweak physics at colliders

TOTAL: 56 hours

Recommended books

- M. Thomson, "Modern Particle Physics", Cambridge University Press (2013).
- I.J.R. Aitchison and A.J.G Hey, "Gauge theories in particle physics", Vols. I and II, IoP publishing, 3rd Ed. (2003).
- F. Halzen and A.D. Martin, "Quarks and leptons: an introductory course in modern particle physics", Wiley (1984).
- D.M. Gingrich, "Practical Quantum Electrodynamics", Taylor and Francis (2006).

Other useful texts

- R.K. Ellis, W.J. Stirling and B.R. Webber, "QCD and collider physics", Cambridge (1996).
- E.A. Paschos, "Electroweak Theory", Cambridge (2007).
- B.R. Martin and G. Shaw, "Particle physics", Wiley (1992).
- W.S.C. Williams, "Nuclear and particle physics", Oxford (1991).
- The Review of Particle Physics, `http://pdg.lbl.gov/`
- J.D. Bjorken and S.D. Drell, "Relativistic Quantum Mechanics", McGraw (1964).
- e.g. G. Arfken, "Mathematical Methods for Physicists", Academic Press (1985).
- J. M. Butterworth, "A Map of the Invisible", Windmill Books (2018). This is aimed at the general public, but might be relaxing and helpful...